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High-frequency electron beam motion observed and resolved.

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After implementing several changes to the beamline to reduce the coupling to external physical vibrations (see IR News No. 3 for details), a new much higher frequency source of noise was observed on the measured IR spectra at beamline 1.4.3. Figure 1 shows an example of this where 128 FTIR scans were obtained, and then another 128, with the two measurements ratioed to one another. This results in a signal to noise spectra around a 100% line. The data in the figure show that the noise is not uniform throughout the spectral region, but is instead much more pronounced in the 2 – 8 kHz region. These frequencies are much higher than the physical motion of a mirror could produce, so we had to assume that the extra noise was coming from motion of the electron beam itself.

The frequency dependence of this noise as a function of beam current was measured by placing a spectrum analyzer directly on the IR detector output and stopping the scanning mirror in the interferometer. The spectrum was observed to change as the beam decayed, further indicating that the source is on the electron beam. During 2-bunch mode operations (when the longitudinal feedback system is not operated) we clearly observed the known synchrotron oscillations of the electron beam, and we could follow these oscillations as a function of beam energy. This proved that the FTIR setup was indeed capable of measuring electron beam motion.

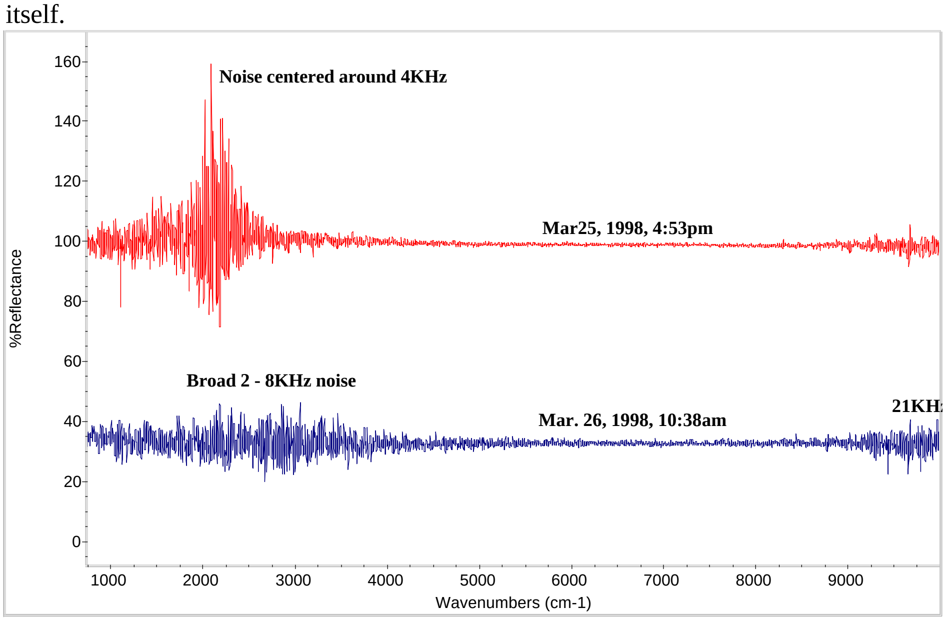

Figure 1. FTIR Spectra showing extra noise in the 2 – 8 kHz frequency regime.

After a presentation given to the Accelerator Physics Group by Michael Martin, John Byrd of that group recognized that the high frequency noise we observed is consistent with a Robinson effect beam motion if something was driving the electron bunches anywhere near these frequencies. John proceeded to set up a monitoring system in the ALS control room where he could measure the longitudinal beam motions. Through several comparisons of the spectra versus beam current we showed that he was indeed measuring the same beam motion that was seen at the IR beamline. Now that the beam motion was confirmed and understood to be an instability in the beam, the search turned toward identifying the driving source of the noise.

There are only a few places in which a high-frequency electric field could interact with the beam, namely the 500MHz RF cavities, the longitudinal and transverse feedback systems, and the pinger. The pinger is not used in regular operations, ruling it out. The fact that we did not observe this high-frequency noise in our earlier studies in the fall of 1997, whereas we do observe them in the winter and spring of 1998 indicates that something changed during that time. A new digitally synthesized master oscillator for the RF system was installed in December 1997 replacing an older crystal oscillator. A careful analysis of the noise output from this synthesizer was performed and showed sideband noise around the primary 500MHz signal. This was therefore the likely culprit.

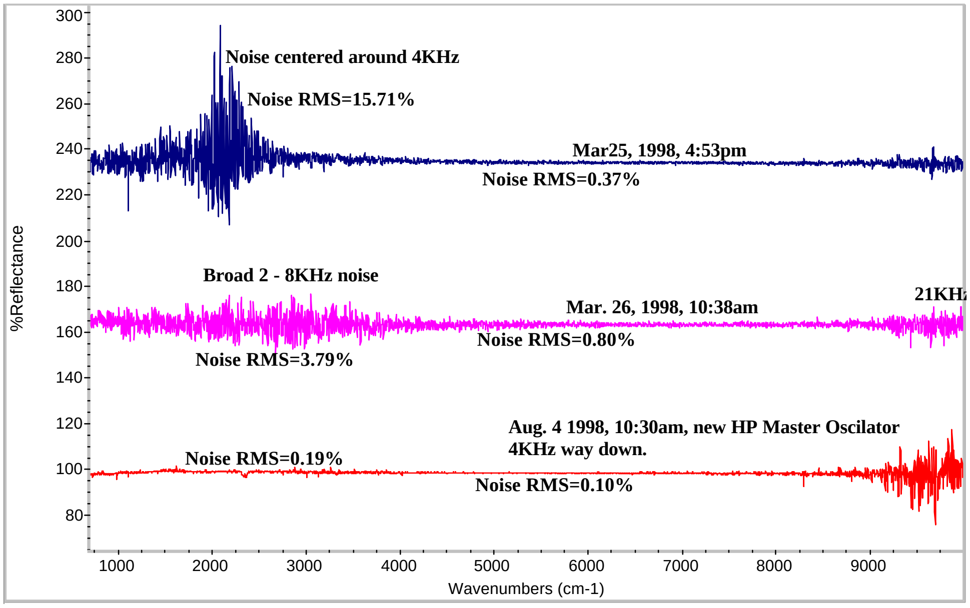

Figure 2. Comparison of the high frequency noise with the old and new digitally synthesized master oscillators.

A new HP digital synthesizer with a lower noise spec was identified and HP loaned a unit to the ALS for testing purposes during the first week of August 1998. This unit was installed in the RF system and testing was done throughout the week to monitor beam motions. The IR spectra measured with the new oscillator is compared to the previous measurements are presented in Figure 2. The lowest spectrum represents the new measurement and clearly the 2 – 8 kHz noise is way down. Indeed most of the deviations from 100% in the 1000 – 4000 cm^{-1} region are actual changes in the water vapor and CO_2 content in the IR path and therefore are real data. The RMS noise values are seen to decrease throughout the spectral region measured. The noise in the spectroscopically critical 1000 – 4000 cm^{-1} region went from unusable, to nearly the same as in the rest of the spectrum. The noise was also seen to be a problem even up above 5000 cm^{-1}, where the RMS noise decreased by up to a factor of eight.

This new HP digital synthesizer has been purchased and was installed onto the RF system permanently on September 14, 1998. Now that the high-frequency noise observed on the beam has been rectified, we can once again turn our attention to the sources of low-frequency motion of the beam, namely vibrations. A quick measurement of the lowest frequency spectral noise features was performed with the quieter synthesizer installed and is shown in Figure 3. The familiar frequencies at 28, 60, 120, and 230Hz are there as well as a peak at 80Hz. Attention must now be returned towards making the RF cavity water pumps quieter and less coupled to the ALS environment. Secondly we will continue decoupling the BL1.4 optics from the walls and floor which are being driven by these water pumps and any other vibration sources in the building. This will include removing the switchyard from the shield wall where it is currently mounted. We also hope to implement more changes to quiet the noise source including rubber-mounting the plumbing, trying variable frequency drives, and possibly physically moving these water pumps further from the ALS floor. Finally, we are testing and installing active-feedback optics to remove remaining beam motions.

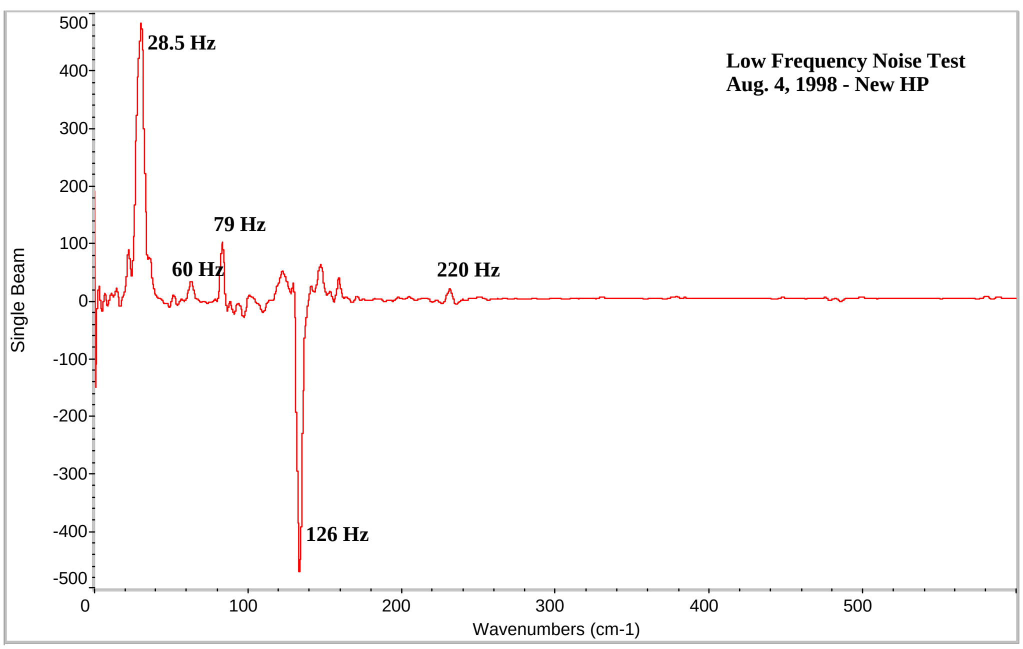

Figure 3. Single FTIR scan showing the frequencies of photon beam motion due to mechanical vibrations.